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Great oxidation event or episodes? Insights from geologic records and coupled photo-biogeochemical models

SHUHEI ONO[1], GARETH IZON[1], BENJAMIN T UVEGES[2] AND ROGER E SUMMONS[1]

[1]Massachusetts Institute of Technology
[2]Cornell University, Ecology and Evolutionary Biology
Presenting Author: sono@mit.edu

Geologic records of sulfur mass-independent fractionation (S-MIF) suggest that the oxygenation of Earth's atmosphere occurred some 2.3 giga-years ago (Ga). Within this broad framework, however, different models call for varying degrees of complexity, with some suggesting a single and irreversible rise of atmospheric oxygen, while others prefer a more protracted and punctuated tajectory[1,2,3]. While this uncertainty is due to the paucity and fragmentary nature of the available Paleoproterozoic S-isotope records and their poor correlations, recent reports of isolated S-MIF reappearances after 2.3 Ga posit a dynamic and protracted oxygen evolution[2]. From a feasibility stance, coupled photo-geochemical models allow for multiple oxidation episodes[4,5]. These models predict a highly non-linear response of steady-state pO_2 against the net O_2 flux, meaning that relatively minor oscillations in net O_2 flux can cause pO_2 shifts between low (<1ppm) and high states (0.2%). Presenting a model that evaluates potential biogeochemical feedback mechanisms, we will explore the conditions necessary to promote MIF-erasing oxygenation events and argue that the relative strengths of potential negative feedback mechanisms (e.g., redox-dependent phosphate regeneration[6] or oxidative weathering[7]) could stabilize pO_2 at Proterozoic levels.[6] Such negative feedback(s) would require a larger perturbation to scrub oxygen from the atmosphere-ocean system once a high-pO_2 state has been attained. We then discuss how this model can be tuned by the detailed stratigraphic and updated record of the transition from S-MIF to sulfur mass-dependent fractionation signals recorded in the Rooihoogte and Timeball Hill formations in the Transvaal basin, South Africa[1,3].

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